



Total 'rib'-preservation technique of internal mammary vessel exposure for free flap breast reconstruction: A 5-year prospective cohort study and instructional video



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HIGHLIGHTS

- We review the rib-preservation technique for internal mammary vessel exposure by a single surgeon.
- An instructional video is presented depicting how to perform the rib-preserving technique step by step.
- The 'rib'-preservation technique to dissect the internal mammary vessels is safe, reliable and reproducible.

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ABSTRACT

Introduction: The total 'rib'-preservation method of dissecting out the internal mammary vessels (IMV) during microvascular breast reconstruction aims to reduce free flap morbidity at the recipient site. We review our five-year experience with this technique.

Patients & methods: An analysis of a prospectively collected free flap data cohort was undertaken to determine the indications, operative details and reconstructive outcomes in all breast reconstruction patients undergoing IMV exposure using the total 'rib'-preservation method by a single surgeon.

Results: 178 consecutive breast free flaps (156 unilateral, 11 bilateral) were performed from 1st June 2008 to 31st May 2013 in 167 patients with a median age of 50 years (range 28–71). There were 154 DIEP flaps, 14 SIEA flaps, 7 muscle-sparing free TRAMs, 2 IGAP flaps and one free latissimus dorsi flap. 75% of the reconstructions (133/178) were immediate, 25% (45/178) were delayed. The mean inter-costal space distance was 20.9 mm (range 9–29). The mean time taken to expose and prepare the recipient IMV's was 54 min (range 17–131). The mean flap ischaemia time was 95 min (range 38–190). Free flap survival was 100%, although 2.2% (4 flaps) required a return to theatre for exploration and flap salvage. No patients complained of localised chest pain or tenderness at the recipient site and no chest wall contour deformity has been observed.

Discussion & conclusion: The total 'rib'-preservation technique of IMV exposure is a safe, reliable and versatile method for microvascular breast reconstruction and should be considered as a valid alternative to the 'rib'-sacrificing techniques.

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1. Introduction

Autologous free flaps are considered by many to be the optimum technique for post-mastectomy breast reconstruction. Worldwide the internal mammary vessels (IMVs) have become popular as the first choice recipients for the microsurgical anastomoses [1–7]. Their popularity stems from the higher arterial pressure and large

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Venturi effect on venous drainage, comparable vessel size match, improved flap positioning and symmetry, the shorter vascular pedicle requirement compared to the thoracodorsal-subscapular system and allowing two surgeons to sit comfortably opposite each other during the microanastomoses. The IMV's have historically been prepared for microvascular anastomoses by performing the 'rib'-sacrificing technique [1–4] which removes a segment of the third costal cartilage in order to expose the underlying vessels. It provides excellent exposure in a wide space, between the inferior border of the second costal cartilage to the superior border of the fourth costal cartilage. However, several authors have highlighted a number of disadvantages with this approach, namely, increased post-operative local pain and long-term tenderness at the recipient site [8–10]. Furthermore, 5–14% of patients report chest wall contour abnormalities, characterised by visible depression on the medial chest wall [11–14]. In addition, with this more conventional approach the risk of pneumothorax, impaired vascularisation of the sternum and intercostal neuralgia may be increased [5,15–19].

The 'rib'-preservation technique was first described by Parrett et al. [9] in March 2008. It was adopted by the senior author in June 2008, refined [20], and has since been used exclusively for all breast free flaps. It reduces recipient site morbidity and has a number of well documented advantages including: shorter recovery time, decreased long term tenderness at the recipient site and a statistically significant ($p = 0.003$) reduction in postoperative morphine requirements [21], improvement in the overall patient experience and conservation of normal chest wall contour [14,21–23]. Its principal disadvantages are the learning curve (albeit short) and the significantly smaller available space in which to perform the anastomoses. This latter has the potential to lead to an increased ischaemia time and a shorter available vessel length for any revision of the microanastomoses. However, a study has demonstrated no statistically significant increase in ischaemia time with the 'rib'-preservation method compared to the 'rib'-sacrificing technique [20].

This prospective cohort study analyses the 5-year experience of a single surgeon (CMM) and includes an instructional video on how to perform the 'rib'-preservation technique of IMV exposure.

2. Patients & methods

2.1. Data collection

All patients who had undergone free flap breast reconstruction by a single surgeon (CMM), between 1st June 2008 to 31st May 2013 were identified from a prospectively collected free flap

database at Addenbrooke's University Hospital (Cambridge). Their records were reviewed to determine the indications, operative details and reconstructive outcomes. Flap-related complications such as on-table anastomotic revisions, flap re-explorations, vessel thrombosis, flap loss (partial or total) and clinical fat necrosis were recorded.

2.2. Surgical technique (including instructional video)

Supplementary data related to this article can be found online at <http://dx.doi.org/10.1016/j.amsu.2015.08.006>.

Apart from the first four patients in the series the IMV's were prepared in the second intercostal space as it is consistently wider than the third and the IM vein is usually single and thus larger making for easier microsurgical anastomoses (Fig. 1) [3,4,20,25]. The pectoralis major muscle is split along the direction of its fibers using monopolar diathermy for a distance of 5 cm from the sternal edge. Two self-retaining Traver's retractors placed at 90° to one another are used to expose the second and third costal cartilages. The center of the anterior periosteum of the costal cartilage (CC) is incised for 3 cm from the sternal border with a size 10 blade and the incision is extended at either end 90° towards the 2nd space. The periosteum covering the inferior quarter of the 2nd CC and the superior quarter of the 3rd CC is then elevated using a periosteal elevator. It is not always necessary to elevate and excise the perichondrium although it does provide an additional 1–2 mm in the intercostal space. The two leaves of perichondria and the intervening intercostal muscles are then resected starting from the inferolateral corner while exerting gentle upward (vertical) traction on them and the dissection is advanced medially to expose the perivascular fat. Preparation of the vessels themselves then proceeds as in the 'rib'-sacrificing techniques, carefully avoiding damage to the underlying parietal pleura. The time taken to prepare the internal mammary vessels as measured from the start of the splitting of the pectoralis major muscle to dissecting out the IM artery and vein(s) ready for anastomoses was termed "digging time".

The statistical analysis of the data was carried out using Excel 2011 software (Microsoft Corporation). Categorical data were expressed as frequencies and percentages. Continuous data were expressed either as median and range or as mean and standard deviations. All tests were two-sided and the significance level was set as 0.05.

This observational cohort study is compliant with the STROBE checklist [26].

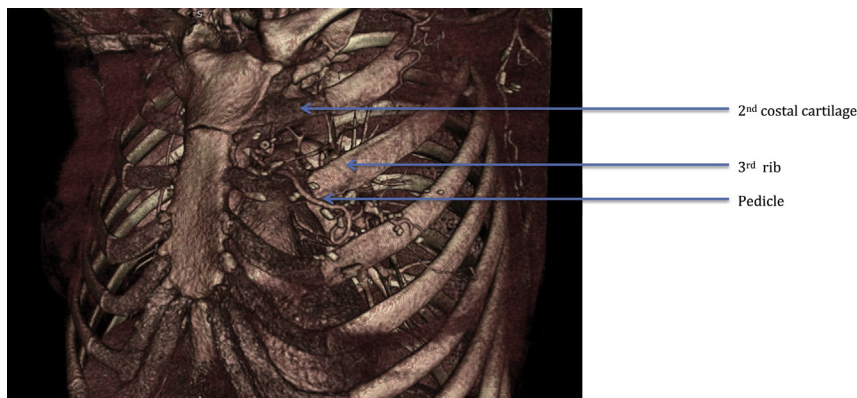


Fig. 1. Three dimensional CT scan showing the microvascular anastomoses and free flap pedicle at the 2nd intercostal space, between the 2nd and 3rd costal cartilages.

Table 1
Distribution of flap types according to the timing of the reconstruction.

Flap type	Immediate (%)	Delayed (%)	Totals (%)
DIEP	116 (65.2)	38 (21.3)	154 (86.5)
SIEA	12 (6.7)	2 (1.1)	14 (7.9)
Ms-TRAM	2 (1.1)	5 (2.8)	7 (3.9)
IGAP	2 (1.1)	0	2 (1.1)
Free LD	1 (0.6)	0	1 (0.6)
Total	133 (74.7)	45 (25.3)	178

Key: DIEP = Deep inferior epigastric artery perforator flap, SIEA = Superficial inferior epigastric artery perforator flap, Ms-TRAM = muscle sparing transverse rectus abdominis myocutaneous flap, IGAP = inferior gluteal artery perforator flap, LD = latissimus dorsi flap.

3. Results

Over the 5-year period, 178 free flaps were performed by the senior author in 167 consecutive patients (median age = 50 years, range 28–71) using the total ‘rib’-preservation technique. Eleven patients (22 free flaps, 12%) underwent bilateral reconstructions and 156 (88%) had unilateral reconstructions. Bipedicled free flaps were counted as one flap despite the four anastomoses and two vascular pedicles. Of the 156 unilateral cases, 57% were left sided and 43% were right sided reconstructions. The timing of the reconstructions (with respect to the mastectomy) was immediate in 75% of patients (133/167) and delayed in the remaining 25% (45/167). Of those 45 patients who underwent delayed reconstructions (47 flaps), only 11/45 (24%) had radiotherapy prior to their reconstruction. In none of these 11 patients were difficulties in dissecting the IMVs encountered and none required a revision of the anastomoses or flap re-exploration. The breast free flaps comprised 154 deep inferior epigastric perforator (DIEP) flaps (87%), 14 superficial inferior epigastric artery perforator (SIEA) flaps (8%), 7 free muscle-sparing transverse rectus abdominis myocutaneous (TRAM) flaps (4%), 2 inferior gluteal artery perforator (IGAP) flaps (1%) and one free latissimus dorsi myocutaneous flap (0.6%). The flap type distribution between immediate and delayed reconstructions is shown in Table 1.

The mean intercostal space distance (ICD) available for the microanastomoses was 20.9 mm \pm 3.4 with a range of 9–29 mm. Fig. 2 depicts the mean ICD for all 178 patients and compares the mean ICDs of patients who did not require re-explorations versus those that had on-table revisions of anastomoses and/or a return to

theatre. It demonstrates that there was no statistically significant difference between these parameters ($p = 0.31$). The mean time taken for exposure of the IMV's (the so called ‘digging time’) was 54 min \pm 29.6. Overall, over the five year period, there was a trend towards a shorter ‘digging time’ of the IMV's as demonstrated in Fig. 3. The flap ischaemia time also varied widely but had a mean of 95 min \pm 24.2 (range = 38–190 min) (Table 2). The arterial microanastomoses were always performed end-to-end using interrupted 9.0 monofilament nylon sutures. In contrast the venous anastomoses were either sutured (9/0 continuous nylon sutures) or with a venous coupler. The venous anastomotic couplers, of varying sizes (2.0–4.5 mm), were used in the last 95 cases (53%) all in the latter part of the study (2010–2013). One vein was anastomosed in 78% (125/161) of cases, two in 35/161 (22%), three in 1/161 (0.6%). The number of venous anastomoses was not specified in 17/161 (11%) cases.

Five on-table anastomotic complications were documented (2.8%); in the first, the venous coupler was initially used, but flow was observed to be sluggish. The anastomosis was taken down and hand sewn using a continuous 9/0 monofilament nylon. In the second, the arterial anastomosis was redone three times (without resorting to rib sacrifice) until satisfactory flow was observed; with total flap survival and no subsequent fat necrosis. In the third case the flap became congested intra-operatively so the superficial inferior epigastric vein (SIEV) was anastomosed to a perforating vein of the IMV at the second intercostal space using a 3.5 mm coupler successfully resolving the congestion. The fourth flap became ischaemic intra-operatively and exploration of the anastomoses revealed an arterial thrombus that was thought to have been caused by turbulent flow from a small side branch in close proximity to the arterial microanastomosis. The anastomosis was redone and the flap was successful. The fifth case was a patient with a previous caesarean section scar who had a SIEA flap. The artery thrombosed and it was redone immediately intra-operatively achieving a successful outcome.

The re-exploration rate in this single-surgeon consecutive series was 2.2% (4 cases). Post-operatively one patient who had had a delayed superficial inferior epigastric artery (SIEA) flap underwent re-exploration of the flap at 24 h as the flap was observed to be intermittently dusky in colour. A small external blood clot around the venous anastomosis was found, the anastomosis was patent and did not require revision. The second case (bilateral reconstruction patient) underwent re-exploration and flap salvage the

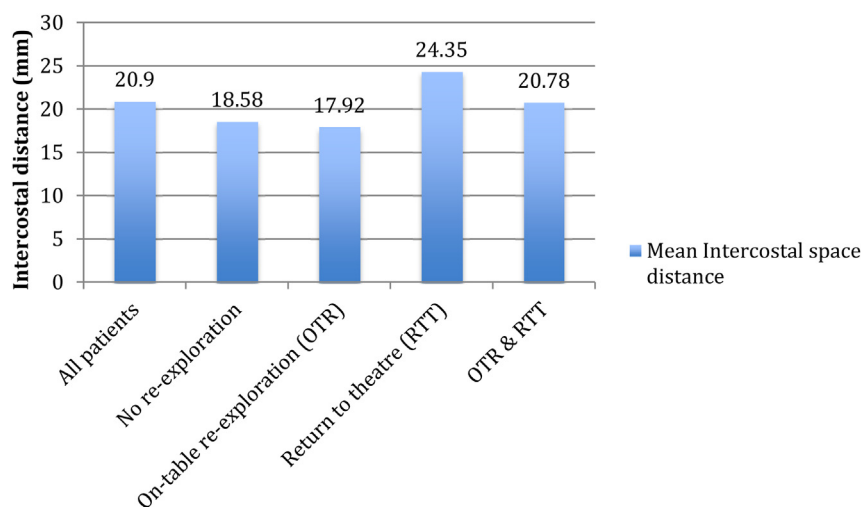


Fig. 2. Mean intercostal space distance in all 178 patients and in those undergoing re-explorations.

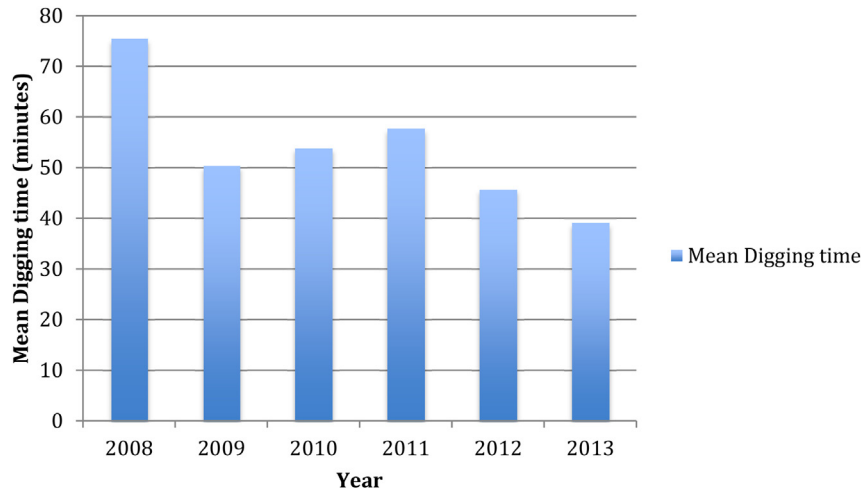


Fig. 3. Temporal change in digging time for exposure of the internal mammary vessels over the five year study period.

following day for venous congestion. The deep system perforator veins were inadequate and at exploration there was a 2 cm long venous thrombus at the anastomosis. A vein graft was used from the superficial SIEV to the IMV. On raising the flap in the third case, the main perforating vein was found to be injured so the SIEV was also anastomosed to a perforator of the IMV. However, two hours later the flap required re-exploration for venous congestion. A foot vein graft was harvested to repair the damaged perforating vein. The fourth case was found to have arterial insufficiency and on revision of the anastomoses it was noted that the back-wall had been “picked up” with a front wall suture causing the rapid arterial thrombosis. The anastomosis was re-done satisfactorily. Free flap survival in this 5 year series was 100%.

There have been no complaints from patients regarding localised chest pain or tenderness at the recipient site and no subjective or objective chest wall contour deformity recorded during the clinical follow-up of minimum three years. Clinical examples of patients undergoing immediate and delayed breast reconstructions are illustrated in Figs. 4 and 5.

4. Discussion

Plastic surgery is characterized by technical innovations designed to improve patient outcomes whilst at the same time minimising patient morbidity. Perforator free flaps were a major advance in reducing the morbidity of autologous breast reconstruction at the donor site. In contrast, efforts to reduce recipient site morbidity have been slower to develop and we believe this deserves as much attention. The ‘rib’-preservation technique for IMV exposure is a real alternative to the more commonly performed ‘rib’-sacrificing technique [9,14,23]. The significant advantages that the ‘rib’-preservation technique provides patients are now well documented and include a reduction of the recipient site morbidity, shorter recovery time and reduced analgesic

requirements [14,21,23].

The results from this five year prospective cohort study is the second largest reported series (in the English language literature) after the Swedish study by Darcy et al. [14], and independently demonstrates the reliability and reproducibility of this technique. The main disadvantage of ‘rib’-preservation is the significantly smaller available intercostal space in which to perform the anastomoses. This could potentially lead to an increase in the ischaemia time, particularly with trainees or established surgeons switching to the ‘rib’-preservation technique. However, studies have not found a statistically significant difference in flap ischaemia times when comparing ‘rib’-preserving and ‘rib’-sacrificing microsurgical breast reconstructions [20,27]. In addition, our results show there was no statistically significant difference in intercostal space distance in those patients who underwent a re-exploration compared to those that did not (Fig. 2).

After 5 years of routine and exclusive total ‘rib’-preservation in 178 consecutive cases we have demonstrated that the intercostal space distance available for microanastomoses varies between 1 and 3 cm with an average of 2 cm. The senior author consistently uses disposable single clamps prior to dividing the vessels (Fig. 6) and a double Acland clamp (2 V) for the arterial anastomoses (Fig. 7). Despite ‘rib’-preservation there was sufficient space to place 3–4 clamps comfortably and allow vessel rotation in the space without undue tension, twisting or damage of the artery, in order to suture the back wall. In addition, the intercostal space provided by the ‘rib’-preservation technique is adequate to perform double-pedicled free flaps involving four or more separate anastomoses (Fig. 8). [Over the last 3 years of the study with local changes in eligibility criteria for microvascular breast reconstruction, double-pedicled free flaps (Fig. 8) have comprised 20% of the senior author’s reconstructions]. In those cases where the intercostal distance is very small, for example 9 mm, we would advise resection of the perichondrium from the inferior half of the 2nd costal cartilage and the superior half of the 3rd costal cartilage in order to gain an additional 1–2 mm as it is in these very small spaces where any additional space can significantly aid the microsurgery. This problem is, however, circumvented by the use of the wider 2nd intercostal space in preference to the 3rd space. None of our patients needed such enlargement of the space.

One of the main potential drawbacks of performing the ‘rib’-preservation technique in the second intercostal space relates to the shorter cephalad available vessel length should there need to be any revision of the microsurgical anastomoses. In all our revisions

Table 2
Mean intercostal distance, IMV preparation time and ischaemia time in patients undergoing free flap breast reconstruction with the total rib preservation technique.

	Mean	Range
ICS distance	20.9 mm	9–29
IMV preparation time	54 min	17–131
Flap ischaemia time	95 min	38–190

Key: ICS = intercostal space, IMV = internal mammary vessel.

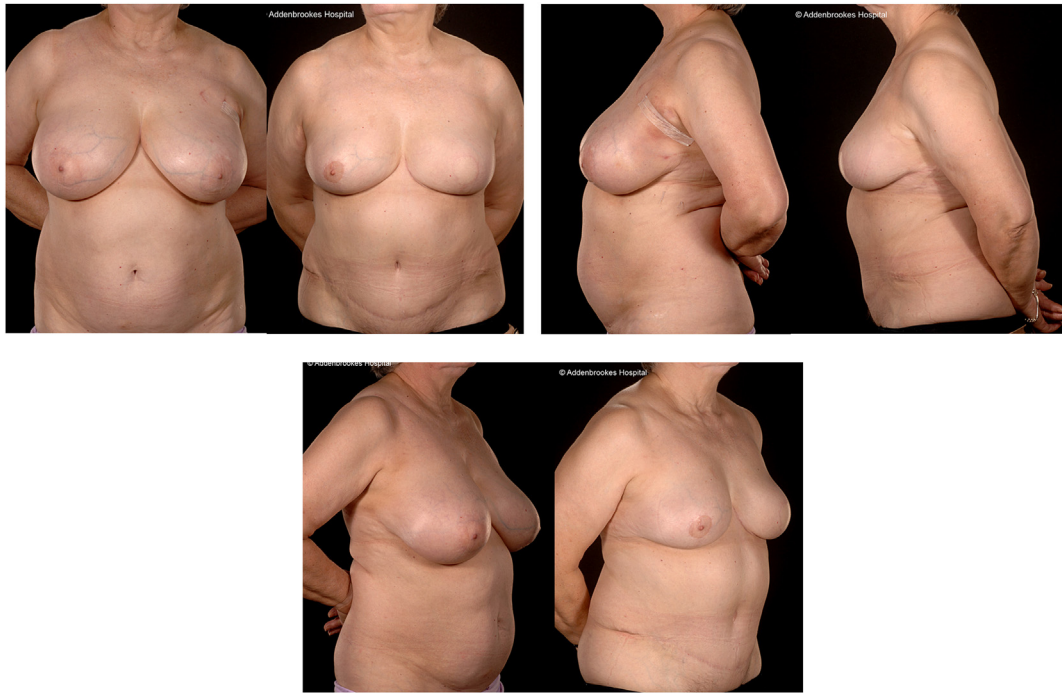


Fig. 4. Pre-operative and 20-month post-operative photographs of a 69 year old patient who underwent a left immediate DIEP flap reconstruction using a Lejour pattern mastectomy for breast cancer and a simultaneous right symmetrising Lejour breast reduction. This patient declined nipple areolar reconstruction and did not undergo radiotherapy. Note the lack of contour deformity/fullness in the superiomedial pole of the left reconstructed breast.

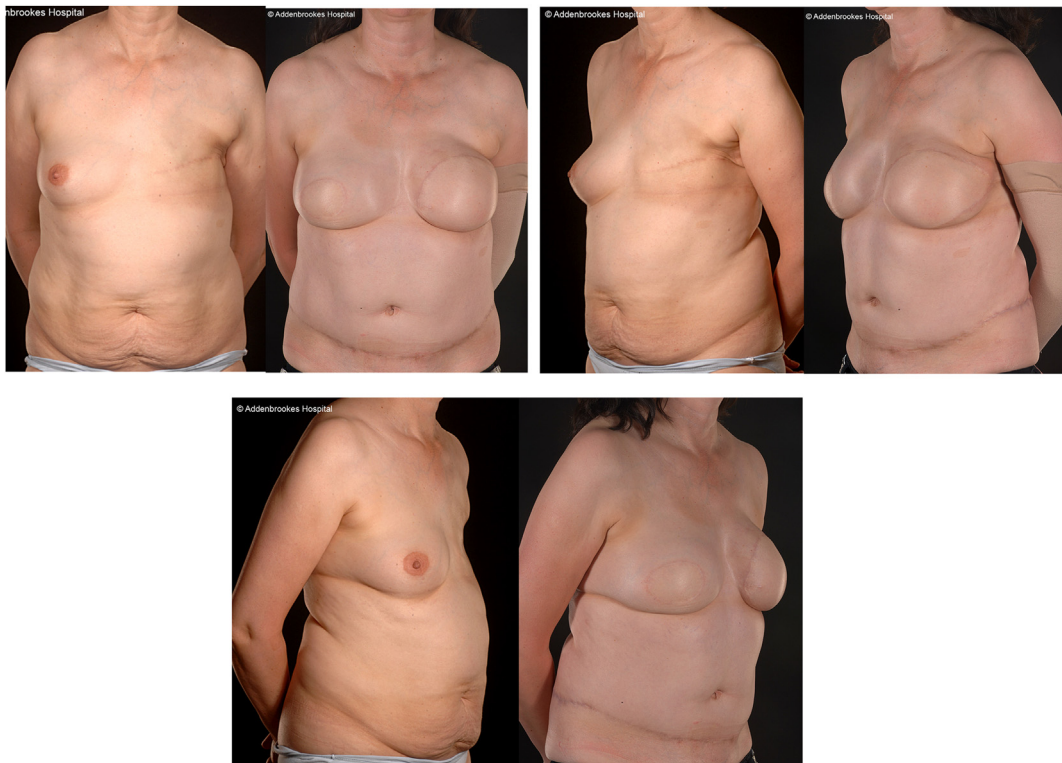


Fig. 5. Pre-operative and post-operative photographs of a 53 year old patient 18 months after a left delayed DIEP reconstruction (29 months between left mastectomy and delayed DIEP) and immediate right DIEP reconstruction. This patient declined nipple areola reconstruction or any other adjustment surgery. Please note the improved superior contour despite the severe postmastectomy deformity prior to delayed reconstruction. She underwent radiotherapy to the left side.

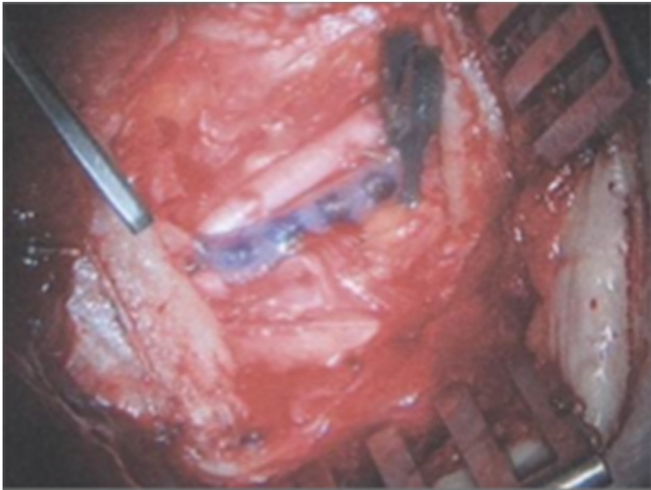


Fig. 6. Single disposable P2 vessel clamp on the internal mammary vein prior to vessel division showing the space available between two rib cartilages.

(both on-table and subsequent ones) this did not prove to be a problem as the 2nd space was found to be adequate for re-anastomoses. Unlike the original description of the ‘rib’-sparing approach by Parrett et al. [9], which described using the third intercostal space for IMV exposure, the second intercostal space is strongly favoured by the senior author as this space is consistently wider than the third [3,4,25]. It must be noted that the smallest ICD of 9 mm in our series was in the third intercostal space which was one of the main reasons which prompted the preferential use of the second intercostal space. In addition, in 70% of cases there are two veins that unite to form a single internal mammary vein and in most cases it is single at the level of the second intercostal space and hence of larger caliber [3,4,14,25]. This in turn makes the venous anastomoses easier and makes the flap more reliable in relation to its venous drainage. In cases where a revision of the anastomoses is required and there is no sufficient available vessel length cephalad, we would suggest nibbling the second costal cartilage with a bone rongeur in order to gain a few millimeters of vessel length cephalad. In those rare cases where this manoeuvre does not prove successful the anastomosis could be performed

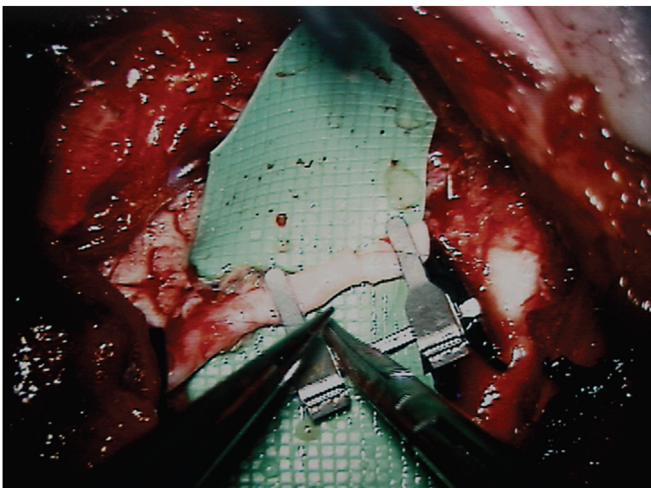


Fig. 7. Double Acland (2 V) clamp and background following division of internal mammary artery, ready for a sutured anastomosis.

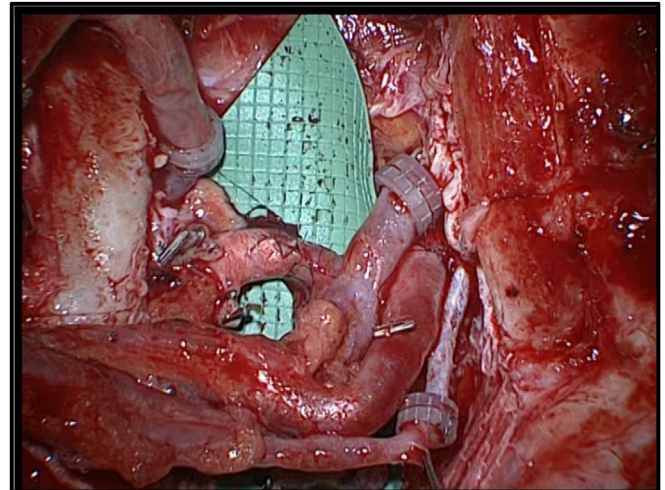


Fig. 8. Bipediced deep inferior epigastric artery perforator flap with 5 completed anastomoses between the completely preserved 2nd and third costal cartilages: (from right to left a couplered anterograde lateral venous anastomosis, a hand-sewn anterograde arterial anastomosis, a couplered anterograde medial venous anastomosis, a hand-sewn retrograde-flow arterial anastomosis [with a green background underneath it], and a retrograde couplered venous anastomosis. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

retrograde onto the IMV's [28,29]. A number of authors have had significant success with retrograde free flaps onto the IMV's. If further difficulties were encountered and it was not possible to use the IMV's, other options would include converting to a ‘rib’-sacrificing technique or using the thoracodorsal vessels as the recipients, although we have never had to resort to these.

We were able to perform the total ‘rib’-preservation technique in all our cases, without having to partially resect any costal cartilages apart from one patient in whom the IM vein was ‘absent’ as it was encased in tumour and extensive scar tissue and the 2nd CC had to be resected to expose usable vein [30]. This is in contrast to Kim et al.'s experience where 79% had total ‘rib’-preservation exposure of the IMV's and 21% required partial trimming of the upper border of the lower rib cartilage [31]. However, it must be noted that Kim et al. used the second and third intercostal spaces in 46 and 54 cases respectively. We consistently used the wider, second intercostal space which may have accounted for this difference. Furthermore, the mean intercostal space distance in Kim et al.'s study was smaller, 18 mm, in contrast to our mean of 21 mm. This could perhaps be attributed to the different ethnicity of the populations studied as the vast majority of our patients were Caucasians compared to Kim et al.'s study which consisted mainly of Asian patients [31] who in general have smaller builds than Caucasian patients. Patient stature (or height) is, however, not a reliable proxy for intercostal space distance [27].

Recently, a concern has been raised in the literature, regarding the integrity and quality of the IMV's following radiotherapy [32]. The preliminary findings from a comparative study on histological analysis of IMV's after radiotherapy prior to microsurgery, suggest significant lesions on the IMV's caused by radiotherapy, with an important difference in the integrity between the retrocostal segment compared to the intercostal segment with the retrocostal segment better preserved [32]. Others, however, have reported that the retrocostal segment may be strongly adherent to the rib post-radiotherapy and thus difficult to dissect. It is well known that radiotherapy causes fibrotic changes around the IMV's and can often make dissection more challenging, (although in experienced hands this is usually surmountable). Three quarters of our

reconstructions were immediate, with only 25% delayed reconstructions. Of those 25% only 24% underwent radiotherapy prior to their reconstruction. None of these patients required a revision of the anastomoses or a re-exploration of the flap due to venous congestion or flap ischaemia. Although our numbers of delayed reconstructions with prior radiotherapy are small, none of our patients suffered flap complications as a result of their radiotherapy. We would therefore argue that the 'rib'-preservation technique is also safe and reliable in patients who have had radiotherapy as given in the UK. Our flap outcomes are comparable to those achieved by others in total rib sacrifice.

During this five year period none of the patients complained of subjective contour deformity at the recipient site and no objective reports were noted on follow-up. In addition, there were no complaints of localised chest pain or tenderness, thus confirming the reduction in recipient site morbidity following the 'rib'-preservation technique when compared to the literature. **Figs. 4 and 5** demonstrate pre-operative and post-operative photographs of patients who have had the 'rib'-preservation technique and where the supero-medial fullness is evident.

5. Conclusion

The 'rib'-preservation technique of internal mammary vessel exposure is safe, reliable and reproducible. Although the space in which to perform the microanastomoses is undoubtedly smaller this technique is not associated with an increase in intraoperative or postoperative flap complications. Furthermore, it reduces the recipient site morbidity and chest wall contour abnormalities and should therefore be considered as a reliable alternative to the more commonly performed 'rib'-sacrificing technique.

Ethical approval

Written consent was obtained from all relevant patients for use of their photos for publication.

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Author contribution

Anais Rosich-Medina – study design, data collection, data analysis, writing.

Serafeim Bouloumpasis – data collection, data analysis.

Michele Di Candia – data collection, editing manuscript.

Charles Malata – study design, data collection, data analysis, editing manuscript.

Conflict of interest statement/funding declaration

None of the authors have any personal or financial relationships with people/organisations that could inappropriately influence this work. There were no external sources of funding.

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